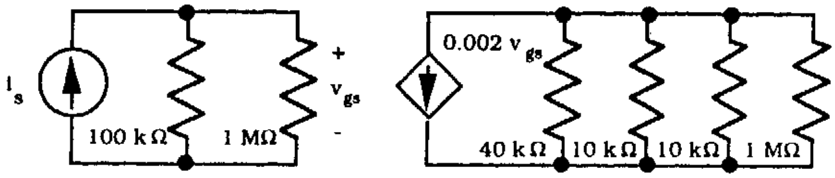
Homework Assignment No. 13 - Solutions

18.22



$$y_{11}^F = \left.\frac{i_1}{v_1}\right|_{v_2=0} = 10^{-6}S \quad | \quad y_{22}^F = \left.\frac{i_2}{v_2}\right|_{v_1=0} = 10^{-6}S \quad | \quad y_{12}^F = \left.\frac{i_1}{v_2}\right|_{v_1=0} = -10^{-6}S$$

$$v_{gs} = i_s(100k\Omega \| 1M\Omega) = (90.9k\Omega)i_s \quad | \quad v_o = -(2x10^{-3})v_{gs}(40k\Omega \| 10k\Omega \| 10k\Omega \| 1M\Omega)$$

$$A = \frac{v_o}{i_s} = -(2mS)(4.44k\Omega)(90.9k\Omega) = -8.08x10^5$$

$$A_{TR} = \frac{A}{1+A\beta} = \frac{-8.08x10^5}{1+(-8.08x10^5)(-10^{-6})} = \frac{-8.08x10^5}{1.81} = -446\ k\Omega$$

$$R_{IN} = \frac{(100k\Omega \| 1M\Omega)}{(1+A\beta)} = \frac{90.9k\Omega}{1.81} = 50.2\ k\Omega$$

$$R_{OUT} = \frac{(40k\Omega \| 10k\Omega \| 10k\Omega \| 1M\Omega)}{(1+A\beta)} = \frac{4.44k\Omega}{1.81} = 2.45k\Omega$$

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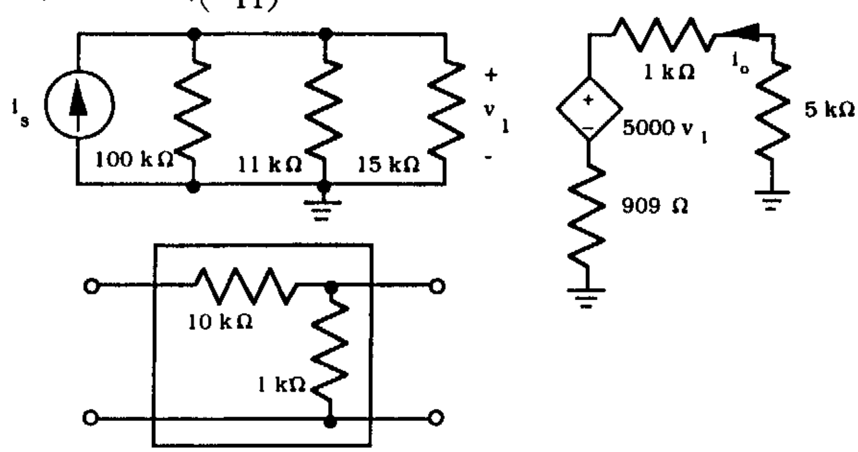
$$g_{11}^F = \left.\frac{i_1}{v_1}\right|_{i_2=0} = \frac{1}{11k\Omega} \quad | \quad g_{22}^F = \left.\frac{v_2}{i_2}\right|_{v_1=0} = 1k\Omega \| 10k\Omega = 909\Omega \quad | \quad g_{12}^F = \left.\frac{i_1}{i_2}\right|_{v_1=0} = -\frac{1k\Omega}{10k\Omega + 1k\Omega} = -\frac{1}{11}$$

$$A = \frac{i_2}{i_s} = -(100k\Omega \| 11k\Omega \| 15k\Omega)\frac{5k\Omega}{(5+1+0.909)k\Omega} = -4.32x10^3$$

$$A_I = \frac{A}{1+A\beta} = \frac{-4.32x10^3}{1+(-4.32x10^3)\left(-\frac{1}{11}\right)} = -11.0$$



$$R_{IN} = \frac{(100k\Omega \| 11k\Omega \| 15k\Omega)}{(1+A\beta)} = \frac{5.97k\Omega}{394} = 15.2\ \Omega$$

$$R_{OUT} = (5k\Omega + 1k\Omega + 0.909k\Omega)(1+A\beta) = (6.91k\Omega)(394) = 2.72M\Omega$$

18.24 See Problem 18.16 for the Q-point calculation.

$$g_{11}^F = \left.\frac{i_1}{v_1}\right|_{i_2=0} = \frac{1}{37\ k\Omega} \ \Big|\ g_{22}^F = \left.\frac{v_2}{i_2}\right|_{v_1=0} = 36k\Omega \| 1k\Omega = 973\ \Omega \ \Big|\ g_{12}^F = \left.\frac{i_1}{i_2}\right|_{v_1=0} = -\frac{1k\Omega}{1k\Omega + 36k\Omega} = -\frac{1}{37}$$

$$1k\Omega \| 37k\Omega = 974\ \Omega \ \Big|\ r_{\pi 1} = \frac{100(0.025)}{491\mu A} = 5.09\ k\Omega \ \Big|\ r_{\pi 2} = \frac{100(0.025)}{873\mu A} = 2.86\ k\Omega$$

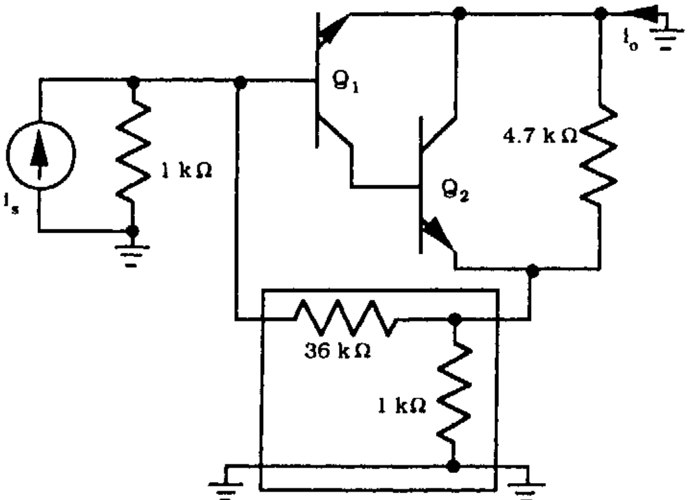
$$A = \frac{i_o}{i_s} = -\frac{974\Omega}{974\Omega + 5090\Omega}(-100)(101)\left(\frac{4700\Omega}{973\Omega + 4700\Omega}\right) = -1340$$

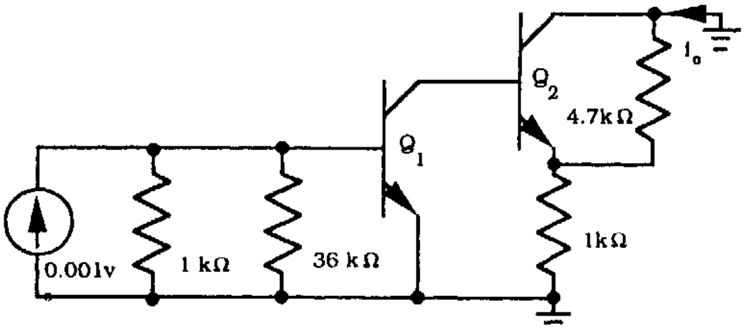
$$A_I = \frac{A}{1 + A\beta} = \frac{-1340}{1 + (-1340)\left(-\frac{1}{37}\right)} = \frac{-1340}{37.2} = -36.0 \ \Big|\ 1 + A\beta = 37.2$$

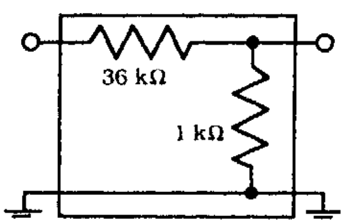
$$A_V = \frac{v_o}{v_s} = \frac{973 i_o}{1000 i_s} = 0.973\frac{i_o}{i_s} = -35.0$$

$$R_{IN} = \frac{\left(1k\Omega \| 37k\Omega \| r_{\pi 1}\right)}{1 + A\beta} = \frac{\left(1k\Omega \| 37k\Omega \| 5.09k\Omega\right)}{37.2} = 22.0\ \Omega \ \Big|\ r_{o1} = \frac{50 + 1.6}{493\text{x}10^{-6}} = 105k\Omega$$

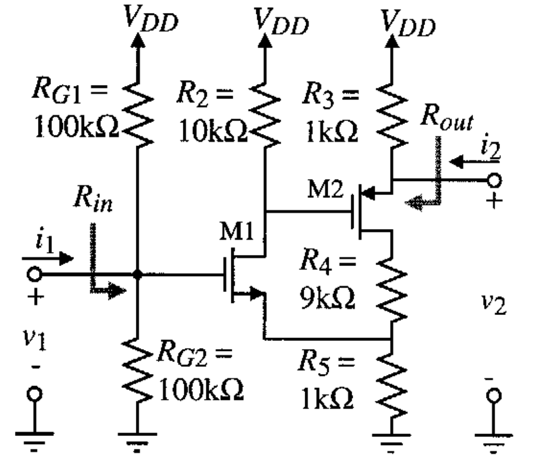
$$R_{OUT} = \frac{\left(1k\Omega \| 36k\Omega \| 4.7k\Omega \Big\| \frac{r_{\pi 2} + r_{o1}}{101}\right)}{1 + A\beta} = \frac{\left(1k\Omega \| 36k\Omega \| 4.7k\Omega \Big\| \frac{5.09k\Omega + 105k\Omega}{101}\right)}{37.2} = 12.5\ \Omega$$







4.) Use the method of feedback analysis to find v_2/v_1, $R_{in} = v_1/i_1$, and $R_{out} = v_2/i_2$. Assume that all transistors are matched and that $g_{m1} = g_{m2} = 1\text{mS}$. Neglect r_{ds}.

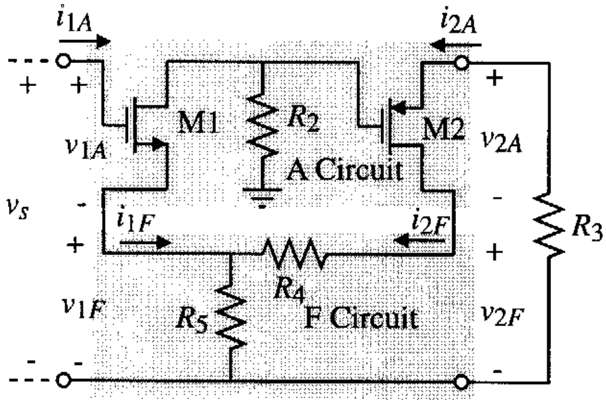


F02H12P4

Solution

The topology is series-series.

The circuit is redrawn below in order to help identify the various terms for the analysis:



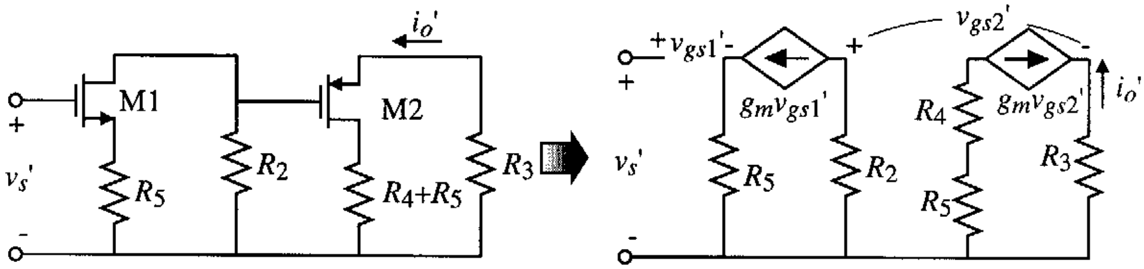
F02H12S4A

$$z_{11F} = \left.\frac{v_{1F}}{i_{1F}}\right|_{i_{2F}=0} = R_5 = 1\text{k}\Omega$$

$$z_{22F} = \left.\frac{v_{2F}}{i_{2F}}\right|_{i_{1F}=0} = R_4 + R_5 = 10\text{k}\Omega$$

$$z_{12F} = \beta = \left.\frac{v_{1F}}{i_{2F}}\right|_{i_{1F}=0} = R_5 = 1\text{k}\Omega$$

Calculation of the A circuit:



F02H12S4B

$$A = \frac{i_o'}{v_s'} = \left(\frac{i_o'}{v_{gs2}'}\right)\left(\frac{v_{gs2}'}{v_{gs1}'}\right)\left(\frac{v_{gs2}'}{v_s'}\right) = (-g_m)\left(\frac{-g_m R_2}{1+g_m R_3}\right)\left(\frac{1}{1+g_m R_5}\right) = (10^{-3})(-5)(-0.5) = 2.5\text{ mS}$$

$$\therefore \frac{i_o}{v_s} = \frac{A}{1+A\beta} = \frac{2.5\text{mS}}{1+2.5} = 0.714\text{mS}$$

Since, $z_{11A} = \infty$, then $R_{in} = 50\text{k}\Omega \| \infty = \underline{50\text{k}\Omega}$

$$\frac{v_2}{v_1} = \frac{-i_o R_3}{v_s} = \frac{-i_o}{v_s} R_3 = -0.714\text{mS}(1\text{k}\Omega) = \underline{-0.714\text{ V/V}}$$

$$R_o = (z_{22T} + R_3)(1+A\beta) = \left(\frac{1}{g_m} + R_3\right)(1+A\beta) = 2\text{k}\Omega(3.5) = 7\text{k}\Omega$$

However, the output resistance specified by the problem, R_{out}, is found as

$$R_{out} = (R_o - R_3) \| R_3 = 6\text{k}\Omega \| 1\text{k}\Omega = \underline{857\Omega}$$

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(a) $$A(s) = \frac{\dfrac{2\text{x}10^{14}\pi^2}{(2\pi\,\text{x}10^3)(2\pi\,\text{x}10^5)}}{\left(1+\dfrac{s}{2\pi\,\text{x}10^3}\right)\left(1+\dfrac{s}{2\pi\,\text{x}10^5}\right)} = \frac{5\text{x}10^5}{\left(1+\dfrac{s}{2\pi\,\text{x}10^3}\right)\left(1+\dfrac{s}{2\pi\,\text{x}10^5}\right)}$$

A(s) represents a low - pass amplifier with two widely - spaced poles

Open – loop: $A_o = 5\text{x}10^5 = 114\text{dB}$ | $f_L = 0$ | $f_H \approx f_1 = 1000$ Hz

(b)A common mistake would be the following:

Closed – loop: $f_H = 1000\text{Hz}\left[1 + 5\text{x}10^5(0.01)\right] = 5\text{MHz}$

Oops! - This exceeds $f_2 = 100$ kHz! This is a two - pole amplifier.

$$A_V(s) = \frac{\dfrac{2\text{x}10^{14}\pi^2}{(s+2\pi\,\text{x}10^3)(s+2\pi\,\text{x}10^5)}}{1+\dfrac{2\text{x}10^{14}\pi^2}{(s+2\pi\,\text{x}10^3)(s+2\pi\,\text{x}10^5)}(0.01)} = \frac{2\text{x}10^{14}\pi^2}{s^2 + 1.01(2\pi\,\text{x}10^5)s + 2\text{x}10^{12}\pi^2}$$

Using dominant - root factorization: $f_1 = 101$ kHz, $f_2 = 4.95$ MHz

So the closed - loop values are $f_H = 101$ kHz and $f_L = 0$.
